ADVANCED COMPOSITE ELEVATOR FOR BOEING 727 AIRCRAFT

22 AUGUST 1979

NINTH AND LAST QUARTERLY TECHNICAL PROGRESS REPORT
23 MAY 1979 THROUGH 22 AUGUST 1979

(NASA-CR-168450) ADVANCED COMPOSITE ELEVATOR FOR BOEING 727 AIRCRAFT Quarterly Technical Progress Report, 23 May - 22 Aug. 1979 (Boeing Commercial Airplane Co., Seattle) 22 p
N82-72161
Unclas
00/05 32657

PREPARED FOR
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

IN RESPONSE TO
CONTRACT NAS1-14952
DRL LINE ITEM NUMBER 018

BOEING COMMERCIAL AIRPLANE COMPANY
P.O. BOX 3707
SEATTLE, WASHINGTON 98124

32657

Boeing Commercial
Airplane Company
Contract NAS1-14952

This Report is Submitted in Compliance
With DRL Line Item Number 018

NINTH QUARTERLY TECHNICAL PROGRESS REPORT
23 May 1979 through 22 August 1979

Supervised by: O. E. Desper, Jr.
O. E. Desper, Jr.
Program Administration and Data Manager

Approved by: Howard Syder
H. Syder
Engineering Design Manager

Approved by: R. W. Johnson
for
J. E. McCarty
Engineering Technology Manager

Approved by:
W. D. Grant
Production Manager

Approved by: S. T. Harvey
S. T. Harvey
Director of Advanced Composites Programs

Boeing Commercial
Airplane Company
Contract NAS1-14952

FOREWORD

This report was prepared by the Boeing Commercial Airplane Company, Renton, Washington, under Contract NAS1-14952. It is the ninth and last quarterly technical progress report covering work performed between 23 May 1979 and 22 August 1979. The program is sponsored by the National Aeronautics and Space Administration, Langley Research Center (NASA-LRC). Dr. H. A. Leybold is the Project Manager for NASA-LRC.

The following Boeing personnel were principal contributors to the program during the reporting period: G. N. Roe, Design; R. W. Johnson, Structural Analysis; D. Grant, Production Manager; L. D. Pritchett, Technical Operations Coordinator; and D. V. Chovil, Business Support Manager.

Boeing Commercial
Airplane Company
Contract NAS1-14952

SUMMARY

This is the last quarterly report for the advanced composites elevator for the Boeing 727 commercial transport. Data and activities not included in this report will be included in the program final report that is scheduled for release at the end of the year.

Activities included completion of the repair manual, completion of testing laminates and honeycomb panels cut from the verification hardware, and completion of production activities.

The repair program has been defined, and is being circulated for approval. Test results, from specimens taken from the verification hardware and compared with the ancillary test program coupon data, indicate that the production process produces an acceptable quality laminate. The fifth and final shipset of elevators, tabs, and balance panels was completed July 20, 1979. The assembly shop, along with tooling, has been deactivated. Capability of reactivation for production is being retained. The program is on schedule.

Boeing Commercial
Airplane Company
Contract NAS1-14952

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

SECTION 1.0

INTRODUCTION

The escalation of jet-fuel prices is causing a reassessment of technology concepts and trades used in designing and building commercial airplanes. The task is to incorporate fuel-saving concepts into commercial aircraft design.

The potential weight savings and fuel reduction resulting from the use of advanced composites in aircraft structure, especially primary structure, are significant. However, the lack of technical confidence and cost data has delayed their use in commercial aircraft.

Hardware programs conducted in a production environment are required to establish and demonstrate the safety, operating-life characteristics, and manufacturing cost of advanced composites structure.

Boeing's approach to the problem is to obtain reliable production, technical, and cost data bases by the integration of advanced composites technology development under NASA contracts, which, when combined with company effort, will accelerate the application of advanced composites. This approach addresses these data bases, developing realistic production costs in a commercial transport manufacturing environment. Program emphases were directed toward developing the information needed to obtain an early production commitment decision by management, and the program was conducted in a production environment.

Preliminary developments, as covered in the first quarterly report, were devoted to conceiving, developing, and analyzing alternative design concepts, and the preparation of a technical plan to aid in selecting and evaluating material, identifying ancillary structural development test requirements, and defining full-scale ground-test and flight-test requirements necessary to obtain FAA certification.

The program was built on precontract design activities as well as contracted design activities that considered:

- Program management and plans development
- Establishing design criteria
- Conceptual and preliminary design
- Manufacturing process development
- Material evaluation and selection
- Verification test
- Detail design
- FAA approval plan definition

This report describes work accomplished during the ninth 3-month period of the contract. Activities included completion of the repair manual, completion of testing of verification hardware specimens, and completion of production activities. These activities are described under the headings; Design Analysis, Ancillary Testing, and Production and Operations. The overall program schedule status is summarized in Figure 1-1.

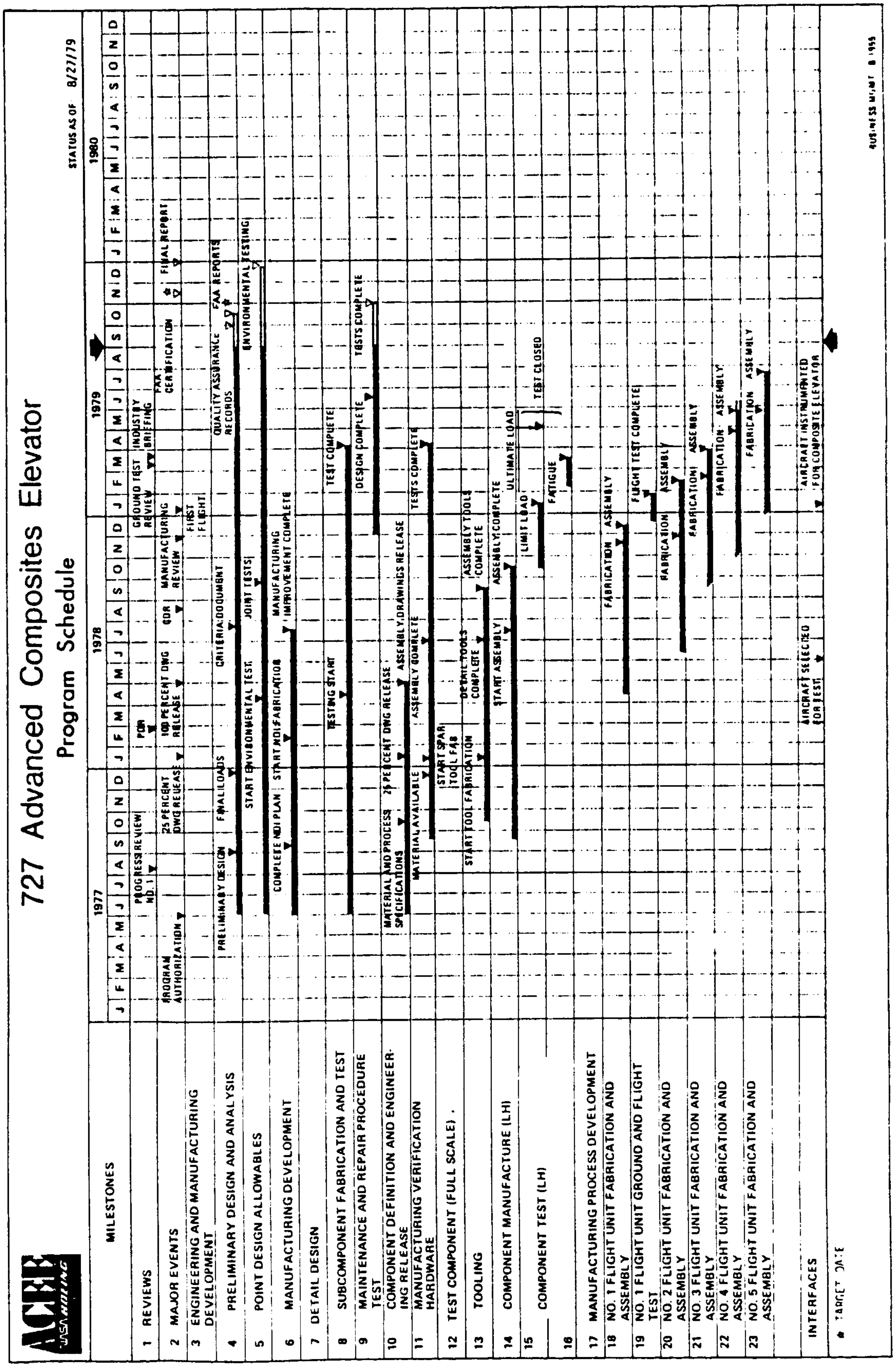


Figure 1-1. Program Master Schedule

SECTION 2.0

DESIGN ANALYSIS

This report will be the last quarterly report for this contract. The design effort is complete. Only minor testing remains in the analysis area, and production of the five and one-half shipsets was completed July 20, 1979.

2.1 DESIGN

A drawing (65C17721) was released that details the specimens used in testing repair techniques for the elevator. A preliminary copy of the repair manual has been completed and is being circulated for approval.

2.2 ANCILLARY TESTING—COUPONS AND ELEMENTS

2.2.1 Production Verification Hardware Coupon Tests

Tests of sections of laminates and honeycomb panels cut from verification hardware have been completed. (See Ancillary Test Plan, reference 1.) The specimen configurations and the areas on the verification hardware, where the specimens were cut from, are shown in drawing 65C17719 (see appendix). Table 2-1, presents the test results. These test results, when compared with the ancillary test program coupon data, indicate that the production process produces an acceptable quality laminate. As noted in Table 2-1, six specimens were fatigue loaded to 500 000 cycles at R = -1.0 at a maximum load equal to 25% of the static ultimate capability. These specimens were then loaded statically to failure. When compared with similar specimens, the residual test results indicate that cyclic loading to 25% of

Table 2-1. Verification Hardware Coupon Test Results

Specimen number 65C17719	Specimen location	Laminate definition ▷4	Specimen width		Nominal thickness		Nominal area		Failure load		Specimen type	Hole diameter		Gross stress		Nominal modulus ▷5		Gross strain mm/mm (in/in)	
			mm	(in)	mm	(in)	mm^2	(in^2)	N	(lb)		mm	(in)	MPa	(lb/in^2)	GPa	$(lb/in^2 \times 10^6)$		
-1	Front spar chord	1	25.43	(1.001)	2.565	(0.101)	65.23	(0.1011)	31 450	(7070)	Tension	4.724	(0.186)	482.2	(69 931)	78.60	(11.4)	0.0061	
-2	Front spar chord	1	25.35	(0.998)	2.565	(0.101)	65.02	(0.1008)	17 660	(3970)	Compression	4.750	(0.187)	271.6	(39 385)	78.60	(11.4)	0.0035	▷3
-3	Front spar chord	1	25.43	(1.001)	2.565	(0.101)	65.23	(0.1011)	33 270	(7480)	Tension	4.750	(0.187)	510.1	(73 986)	78.60	(11.4)	0.0065	▷1
-4	Front spar chord	1	25.43	(1.001)	2.565	(0.101)	65.23	(0.1011)	28 240	(6350)	Tension	4.724	(0.186)	433.1	(62 809)	78.60	(11.4)	0.0055	
-5	Rear spar chord	2	25.40	(1.000)	0.762	(0.030)	19.35	(0.0300)	2 958	(665)	Tension	4.750	(0.187)	152.8	(22 167)	20.68	(3.0)	0.0074	
-6	Rear spar chord	2	25.43	(1.001)	0.762	(0.030)	19.38	(0.0300)	4 937	(1110)	Compression	4.775	(0.188)	255.1	(37 000)	20.68	(3.0)	0.0123	▷3
-7	Rear spar chord	2	25.37	(0.999)	0.762	(0.030)	19.33	(0.0300)	2 615	(588)	Tension	4.750	(0.187)	135.1	(19 600)	20.68	(3.0)	0.0065	▷1
-8	Rear spar chord	2																	▷2
-9	Rib chord	3	25.40	(1.000)	1.905	(0.075)	48.39	(0.0750)	13 300	(2990)	Compression	4.750	(0.187)	274.9	(39 867)	49.64	(7.2)	0.0055	
-10	Rib chord	3	25.40	(1.000)	1.905	(0.075)	48.39	(0.0750)	14 300	(3215)	Tension	4.724	(0.186)	295.6	(42 867)	49.64	(7.2)	0.0060	
-11	Rib chord	4	22.89	(0.901)	1.727	(0.068)	39.53	(0.0613)	10 385	(2335)	Tension	4.750	(0.187)	236.8	(34 338)	43.44	(6.3)	0.0055	
-12	Rib chord	4	22.86	(0.900)	1.727	(0.068)	39.48	(0.0612)	11 300	(2540)	Compression	4.293	(0.169)	257.5	(37 353)	43.44	(6.3)	0.0059	
-13	Skin panel	5	76.40	(3.008)	0.279	(0.011)	21.32	(0.0330)	1 539	(346)	Beam			387.3	(56 169)	54.47	(7.9)	0.0071	▷6
14	Skin panel	5	76.45	(3.010)	0.279	(0.011)	21.33	(0.0330)	1 503	(338)	Beam			378.3	(54 870)	54.47	(7.9)	0.0069	▷6
-15	Front spar web	7	76.15	(2.998)	1.334	(0.0525)	101.58	(0.1575)	33 180	(7460)	Shear	2.489	(0.098)	326.6	(47 365)	29.30	(4.3)	0.0111	
16	Skin edge band - front spar	6	25.43	(1.001)	1.702	(0.067)	43.28	(0.0671)	9 185	(2065)	Tension	4.750	(0.187)	212.2	(30 775)	46.89	(6.8)	0.0045	
17	Skin edge band - front spar	6	25.43	(1.001)			43.28	(0.0671)	12 720	(2860)	Tension	4.750	(0.187)	293.9	(42 623)	46.89	(6.8)	0.0063	
18	Skin edge band - front spar	6	25.43	(1.001)			43.28	(0.0671)	10 185	(2290)	Tension	4.775	(0.188)	235.3	(34 128)	46.89	(6.8)	0.0050	▷1
-19	Skin edge band - front spar	6	25.40	(1.000)			43.23	(0.0670)	10 275	(2310)	Tension	4.775	(0.188)	237.7	(34 478)	46.89	(6.8)	0.0051	▷1
-20	Skin edge band - rear spar	6	25.45	(1.002)			43.32	(0.0671)	7 205	(1620)	Compression	4.775	(0.188)	166.5	(24 143)	46.89	(6.8)	0.0036	▷1 ▷3
21	Skin edge band - rear spar	6	25.45	(1.002)			43.32	(0.0671)	11 610	(2610)	Compression	4.801	(0.189)	268.2	(38 897)	46.89	(6.8)	0.0057	▷1
22	Skin edge band - rear spar	6	25.40	(1.000)			43.23	(0.0670)	11 740	(2640)	Compression	4.750	(0.187)	271.7	(39 403)	46.89	(6.8)	0.0058	
23	Skin edge band - rear spar	6	25.43	(1.001)			43.28	(0.0671)	12 100	(2720)	Compression	4.775	(0.188)	279.5	(40 536)	46.89	(6.8)	0.0060	
24	Skin edge band - rib	6	25.45	(1.002)			43.32	(0.0671)	12 790	(2875)	Tension	4.750	(0.187)	295.4	(42 846)	57.23	(8.3)	0.0052	
25	Skin edge band - rib	6	25.45	(1.002)			43.32	(0.0671)	11 700	(2630)	Tension	4.750	(0.187)	270.2	(39 195)	57.23	(8.3)	0.0047	
26	Skin edge band - rib	6	25.45	(1.002)			43.32	(0.0671)	13 480	(3030)	Compression	4.775	(0.188)	311.4	(45 156)	57.23	(8.3)	0.0054	
27	Skin edge band - rib	6	25.45	(1.002)	1.702	(0.067)	43.32	(0.0671)	11 650	(2620)	Compression	4.750	(0.187)	269.2	(39 046)	57.23	(8.3)	0.0047	
-28	Front spar web	7																	▷2
29	Front spar web	7	76.07	(2.995)	1.334	(0.0525)	101.48	(0.1572)	38 250	(8600)	Shear	2.515	(0.099)	377.2	(54 707)	29.30	(4.3)	0.0129	
30	Skin panel	5	76.45	(3.010)	0.279	(0.011)	21.33	(0.0330)	1 370	(308)	Beam			344.8	(50 000)	54.47	(7.9)	0.0063	▷6
31	Skin panel	5	76.48	(3.011)	0.279	(0.011)	21.34	(0.0330)	1 383	(311)	Beam			348.1	(50 487)	54.47	(7.9)	0.0064	▷6
-32	Skin panel	5	76.45	(3.010)	0.279	(0.011)	21.33	(0.0330)	1 454	(327)	Beam			366.0	(53 084)	54.47	(7.9)	0.0067	▷6
33	Skin panel	5	76.48	(3.011)	0.279	(0.011)	21.34	(0.0330)	1 517	(341)	Beam			381.7	(55 357)	54.47	(7.9)	0.0070	▷6

▷1 Residual strength after fatigue test

▷2 Specimen lost during fabrication

▷3 Invalid test, specimen did not fail in test section

▷4 Structural laminate definition (see 65C17719)—all plies are fabric except as noted

1 — 10 plies 0° tape
  6 plies ±45°
2 — 4 plies ±45°
3 — 4 plies ±45°
  6 plies 0/90°
4 — 4 plies ±45°
  5 plies 0/90°
5 — 1 ply ±45° } Each
  1 ply 90° tape } face
6 — 2 plies 90° tape
  4 plies ±45°
  4 plies 0/90°
7 — 6 plies ±45°

▷5 Modulus in test direction

▷6 Honeycomb panel: 13.97-mm (0.55-in) thick core—0.279-mm (0.011-in) thick face sheet the static ultimate load has no significant effect on the ultimate load capability of the tested configuration.

2.2.2 Repair Specimens Test Plan

The repair program has been defined and the test plan is presented in Table 2-2. The repair specimen is shown in Figure 2-1. This specimen represents a repair for one face sheet with core damage. Test results from this specimen will establish the ultimate inplane strength of the skin panels with this size and type of repair, compared to an undamaged skin

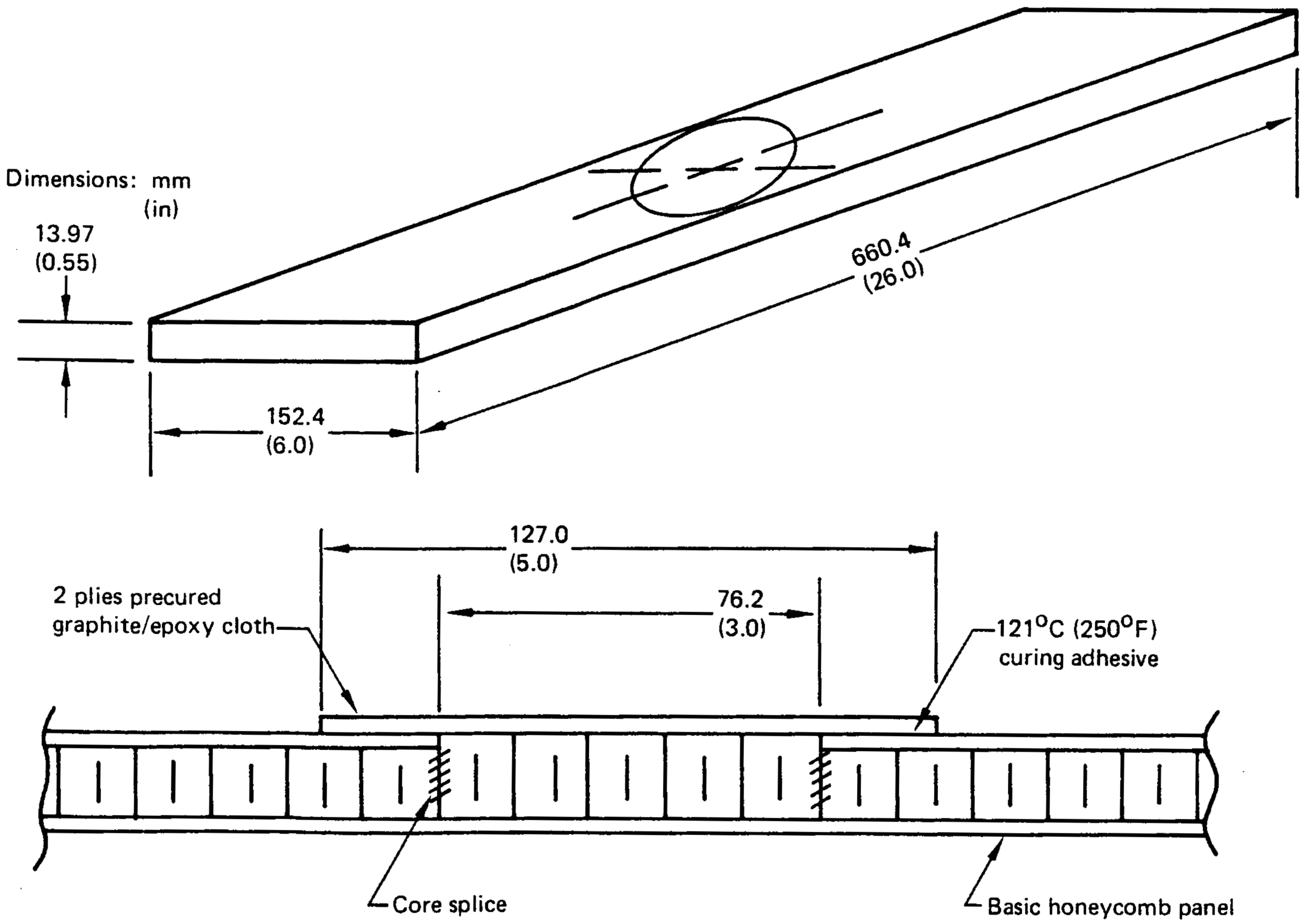


Figure 2-1. Four-Point Beam Honeycomb Repair Specimen (Drawing 65C17721)

Table 2-2. Repair Test Program

Specimen type	Test type	Test condition				
		Dry	Wet	Test temperature		
				-56°C (-65°F)	21°C (70°F)	71°C (160°F)
Baseline (65C17721-4)	Static	D			3	
			W		3	
	Fatigue	D			3	
			W		3	
Damaged/repaired (65C17721-2)	Static	D		3	3	3
			W	3	3	3
	Fatigue	D			3	
			W		3	
Impact damaged (65C17721-4)	Static	D			3	
			W		3	
	Fatigue	D			3	
			W		3	

Note: All specimens tested as four-point beam bending; wet conditioning 1.1 ±0.1% moisture pickup in 2.29-mm (0.09-in) thick rider coupons

panel. The baseline and impact specimens will be the same size as the repaired specimen. The impacted specimen will be tested to determine the residual strength of the elevator skin panel with visually detectable damage. All specimens will be tested as four-point beams, and the repaired and impacted area will be loaded in compression.

2.3 WEIGHT STATUS

The predicted weight status published in the seventh quarterly report is unchanged.

The fourth and fifth elevator system shipsets have been weighed. Component and total weights, together with predicted weights, are as follows:

Component	Number 4 shipset	Number 5 shipset	Predicted
Left-hand and right-hand elevator surfaces	151.3 kg (333.6 lb)	151.5 kg (334.0 lb)	153.4 kg (338.2 lb)
Left-hand and right-hand tab assemblies	6.7 kg (14.8 lb)	6.8 kg (14.9 lb)	6.8 kg (15.0 lb)
Left-hand and right-hand balance panels	29.1 kg (64.1 lb)	28.9 kg (63.8 lb)	29.1 kg (64.2 lb)
Total elevator system/airplane	187.1 kg (412.5 lb)	187.2 kg (412.7 lb)	189.3 kg (417.4 lb)
% reduction	27.3	27.3	26.1

2.3.1 Graphite/Epoxy Elevator Repair Manual

The weight technology portion of the manual has been completed.

SECTION 3.0

PRODUCTION AND OPERATIONS

3.1 ASSEMBLY PROGRESS

The fifth and final shipset of elevators, tabs, and balance panels under the contract was completed July 20, 1979. Status of the five and one-half shipsets fabricated is as follows:

- Left-hand test unit—in Engineering test laboratory
- Number 1 shipset—installed on Boeing flight test airplane
- Numbers 2 through 5 shipsets—in storage, awaiting FAA certification and subsequent installation on line airplanes for inservice evaluation (see fig. 3-1).

Investigation into causes for recurrence of fiber breakout on shipsets number 4 and number 5 external surfaces during drilling operations was completed during the report period. Indications were that the primary contributing factor was the deletion of the polyurethane surfacer that had previously been applied before the primer paint. The surfacer had been eliminated for weight reduction purposes, effective on the fourth shipset. In view of the weight savings, the limited number of breakout occurrences, and the fact that countersink operations clean up or bring breakout to within acceptable limits, no further investigative action is planned and the surfacer will not be reinstated.

The Assembly Shop area and Tooling have been deactivated. Capability for reactivation for production is being retained.

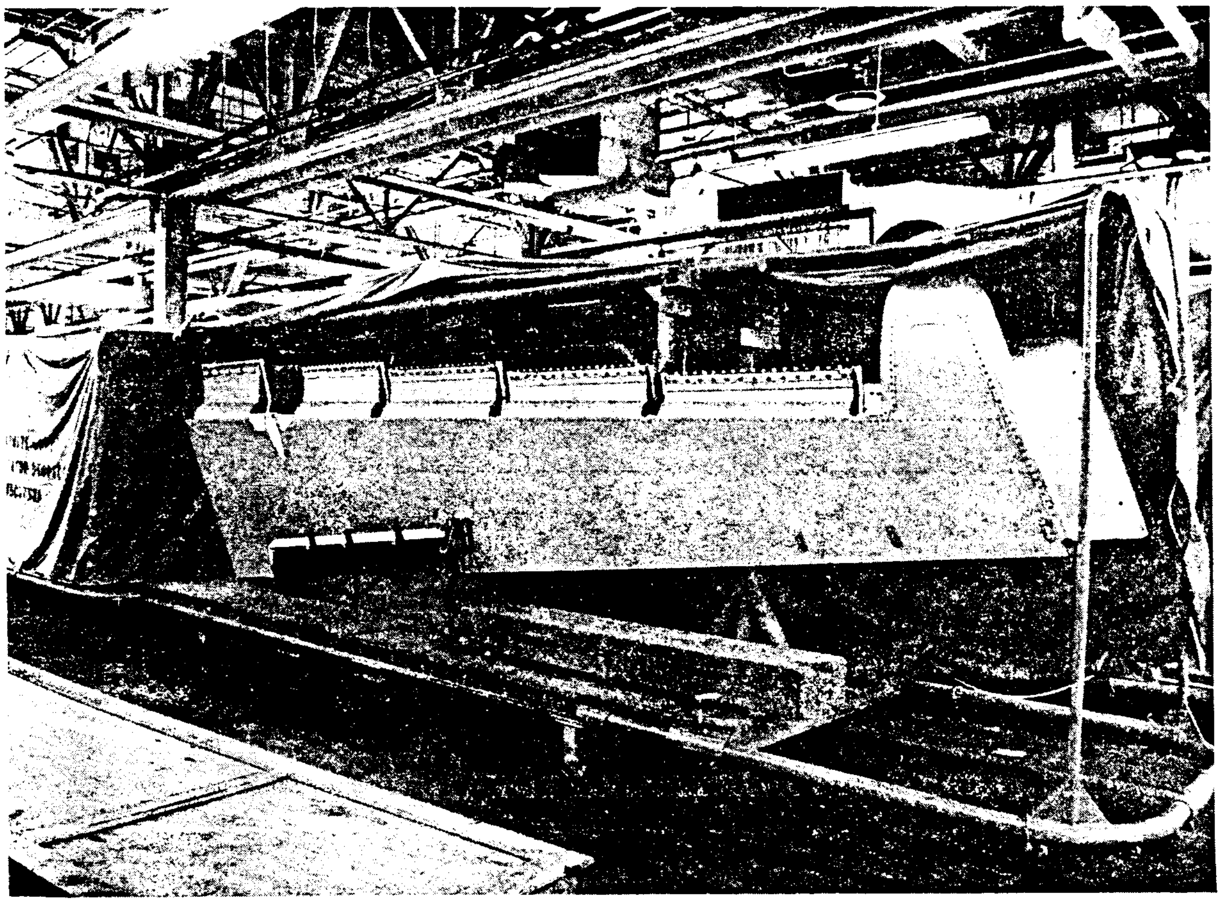


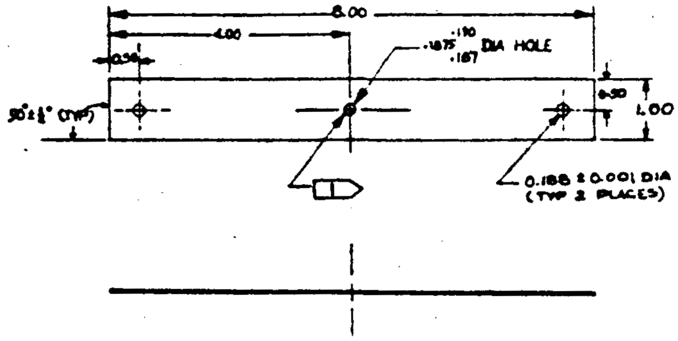
Figure 3-1. Advanced Composites Elevator in Storage Fixtures

SECTION 4.0

REFERENCES

1. "Advanced Composite Elevator for Boeing 727 Aircraft," First Quarterly Technical Progress Report, NASA Contract NAS1-14952, August 1977

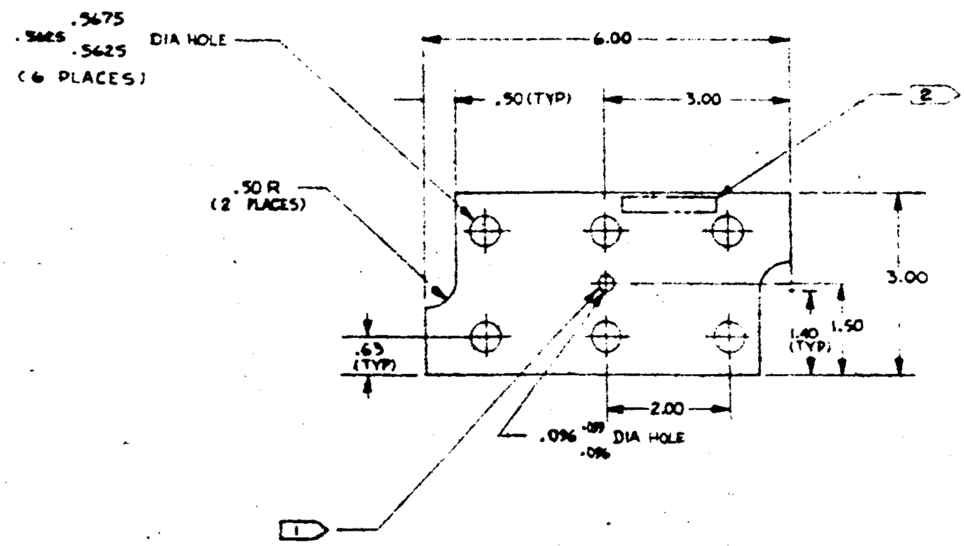
APPENDIX



1C4

(TYP SPECIMEN (-1 THRU -12 & 16 THRU -27)

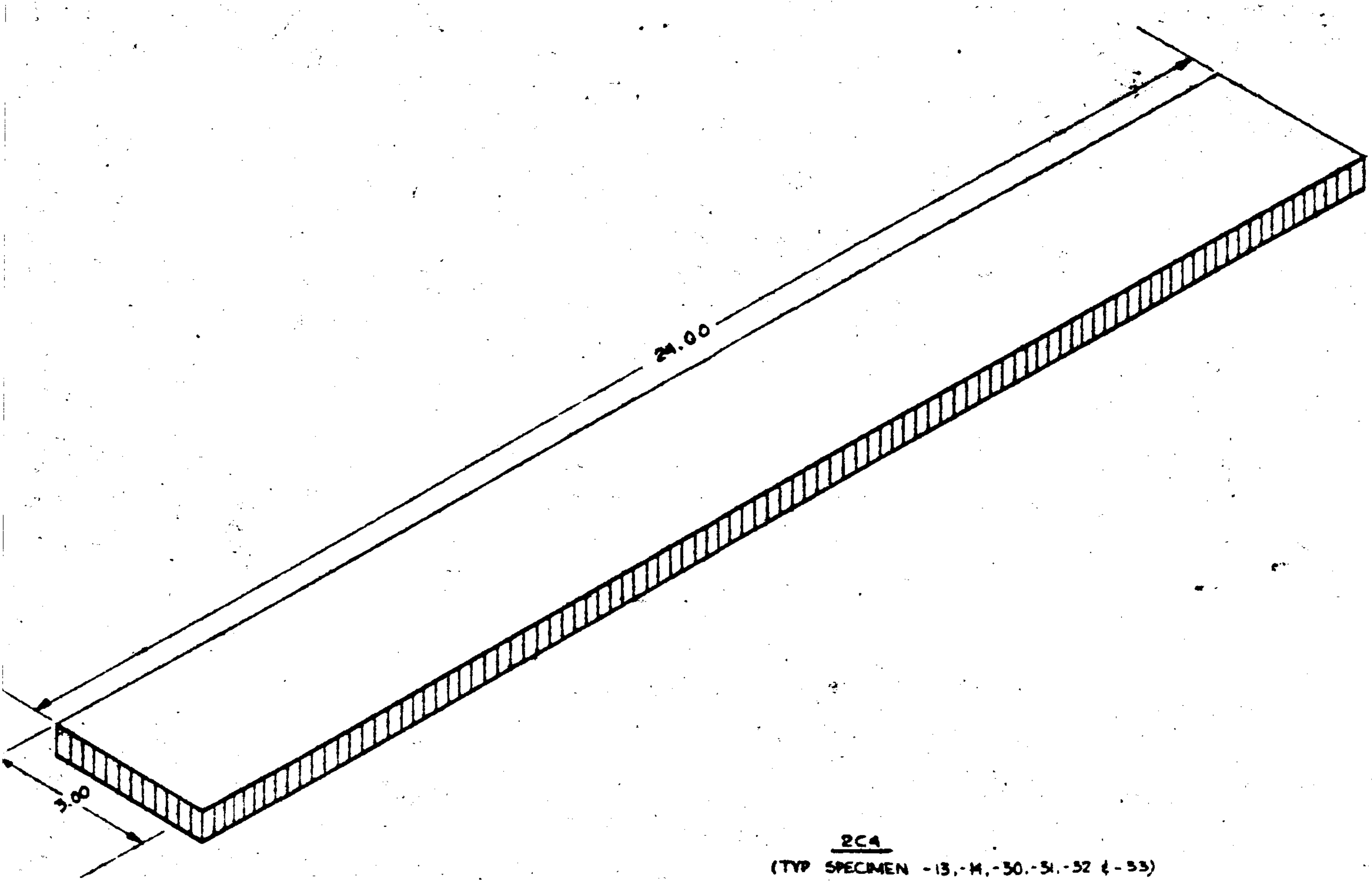
TENSION COMPRESSION & FATIGUE TEST



2C5

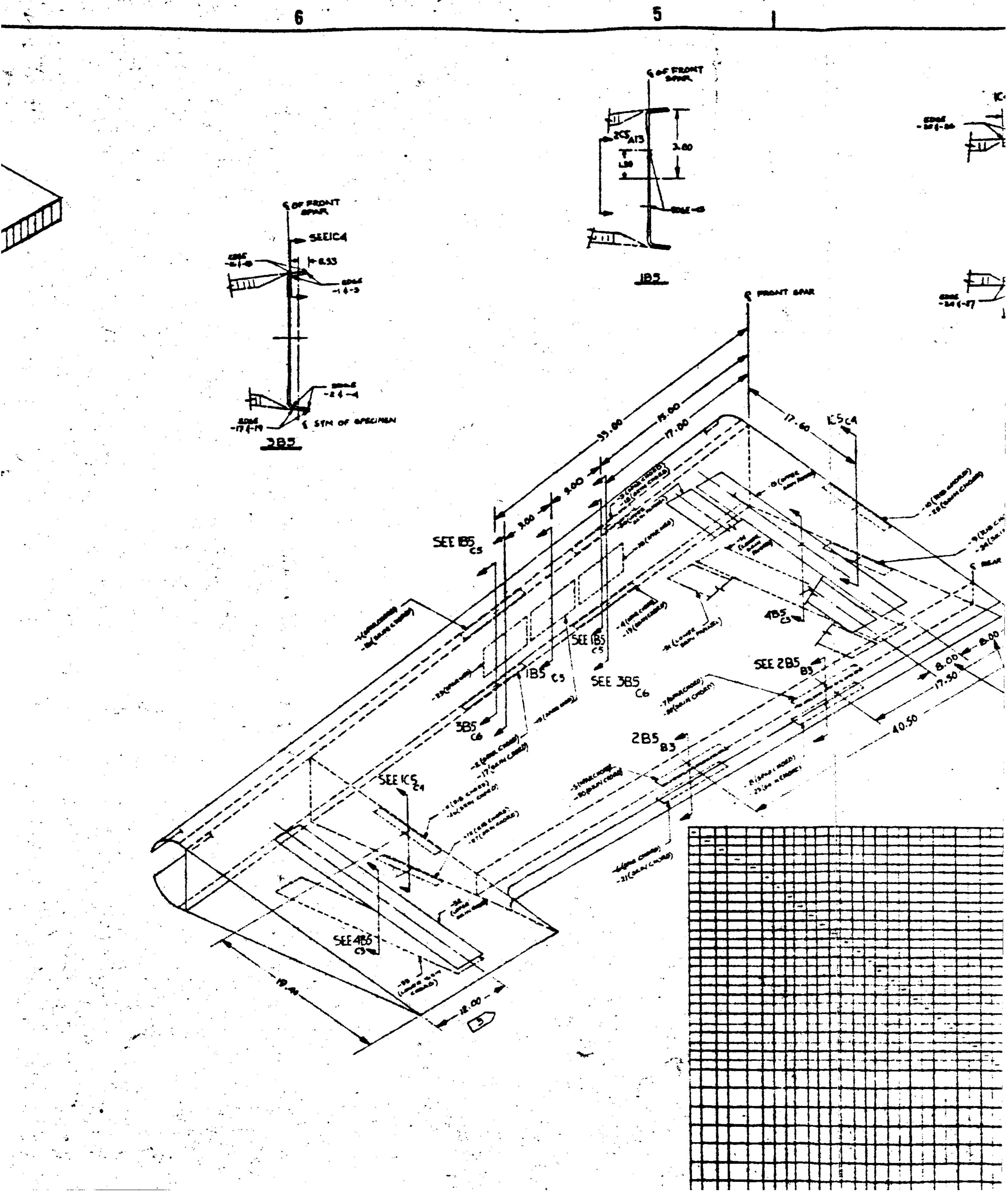
(TYP SPECIMEN -15, -28 & -29)

RAIL SHEAR TEST



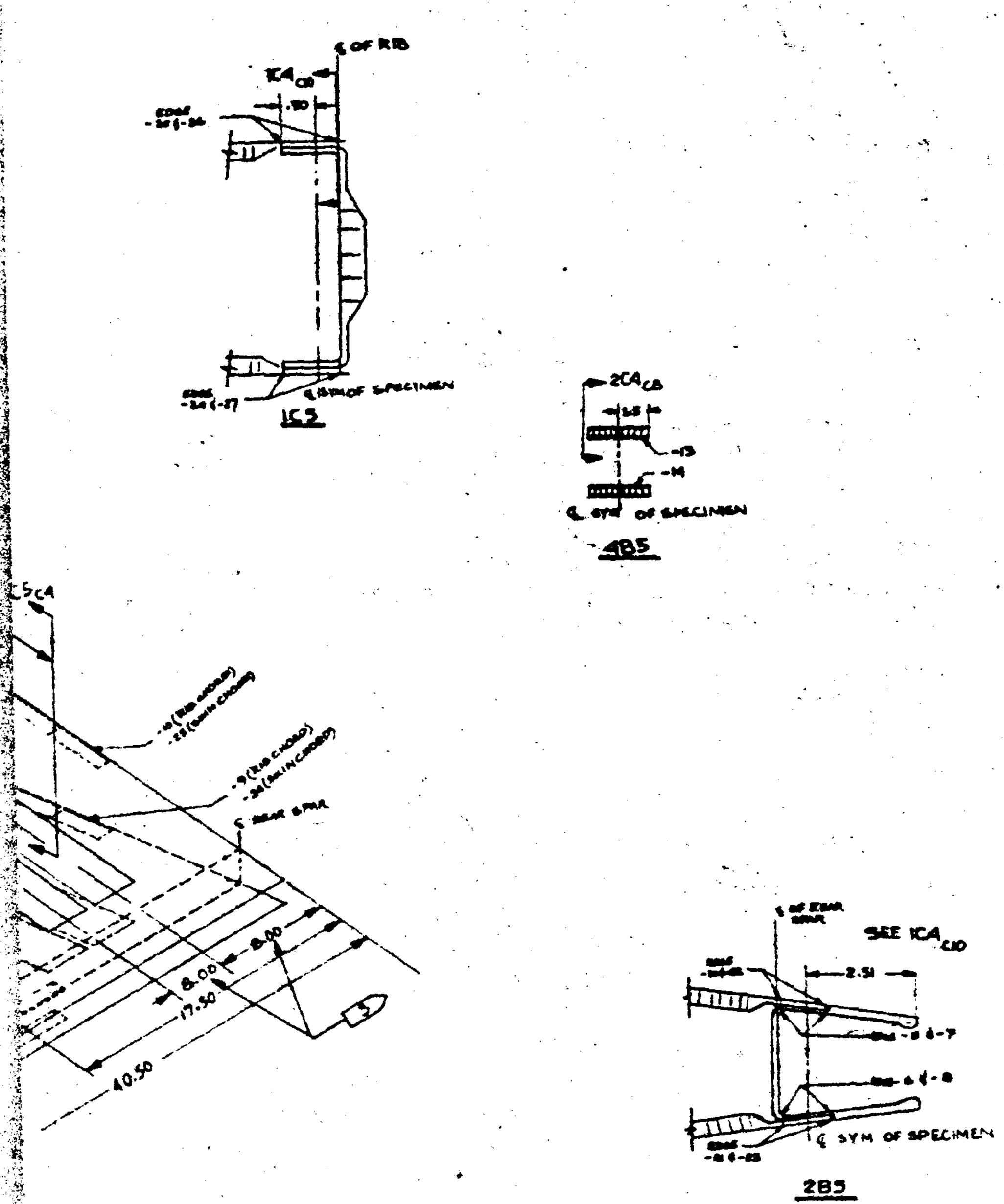
2C4
(TYP SPECIMEN -13,-14,-30,-31,-32 & -33)

LONG BEAM FLEXURE TEST


6
5
℄ OF FRONT SPAR
SEE 1C4
3B5
1B5
℄ FRONT SPAR
℄ STN OF SPECIMEN
33.00
15.00
17.00
17.60
1C5 C4
SEE 1B5 C5
1B5 C5
SEE 3B5 C6
3B5 C6
SEE 2B5 B3
2B5 B3
4B5 C5
SEE 1C5 C4
SEE 4B5 C5
40.50
17.50
8.00
19.40
18.00
℄ REAR
3.00
3.00
3.60

4 3 1

DIMENSIONING & TOLERANCING PER [illegible]
PART MARKING PER BAC 5307
SEE BAC5 [illegible] FOR SURFACE ROUGH[illegible]
FORM, PUNCH, STRAIGHTEN & [illegible] PER BAC [illegible]
BOLT & NUT INSTALLATION PER BAC [illegible]
MATERIAL SUBSTITUTION & [illegible] PER BAC [illegible]
[illegible]
FOR FINISH CODES, SEE DOCUMENT [illegible] &/OR [illegible]



RELEASE -7	-6	-5	-4	-3	-2	-1	QTY REQD	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	MATERIAL AND SPECIFICATION
						—	—	-1			MAKE FROM MANUFACTURING VERIFICATION HARDWARE (CMH 23000)
					—		—	-2			
				—			—	-3			
			—				—	-4			
		—					—	-5			
	—						—	-6			
—							—	-7			

LIST OF MATERIAL

4 3 1

FASTENER SYMBOL CODE

REVISIONS

SYM	ZONE	DESCRIPTION	DATE	APPROVAL

NOTE:

1. FINISHED GRAPHITE/EPOXY SPECIMENS SHOULD HAVE SMOOTH, SHARP CUT EDGES, SQUARE CORNERS & SQUARE EDGES WITH NO TAPERS OR FEATHERED EDGES.
2. ALL SPECIMENS SHALL BE PACKAGED FOR SHIPMENT EITHER INDIVIDUALLY OR IN CONVENIENT-SIZED GROUPS (WITHOUT THE USE OF ADHERING TAPES IN CONTACT WITH THE GRAPHITE LAMINATES).
3. SIDES OF ALL SPECIMENS TO BE PARALLEL WITHIN .015.

1 X-RAY INSPECT HOLE PER QC R&D REQUIREMENTS

2 PART MARKING LOCATION FOR ASSY NO.

3 CENTERLINE OF SPECIMEN TO BE PERPENDICULAR TO FRONT SPAR WEB WITHIN 1°.

A-2

TEST ONLY

NEXT ASSY	USED ON	SECT NO	SERIAL NUMBER	PART NUMBER	RELEASE COLUMN	DRAWING SHEET NUMBER	REV LTR

APPLICATION

CHANGE NO. EWA 1211 LT

DWG ORIG BY GROUP: ADVANCED COMPOSITES

DRAWN S. DAS

PROJ S. DAS 10/4/78

THE BOEING COMPANY
COMMERCIAL AIRPLANE DIVISION RENTON, WASH

MANUFACTURING VERIFICATION HARDWARE TEST SPECIMENS GR/EP ELEVATOR

CODE IDENT NO 81205 SIZE J 65C17719

SCALE NONE

65C17719

EWA 1211 LT